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Indian Standard

GUIDE ON MAINTAINABILITY OF EQUIPMENT

PART III MAINTAINABILITY PROGRAMME

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GUIDE ON MAINTAINABILITY OF EQUIPMENT

PART III MAINTAINABILITY PROGRAMME

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Indian Standard

GUIDE ON MAINTAINABILITY OF EQUIPMENT

PART III MAINTAINABILITY PROGRAMME

0. FOREWORD

0.1 This Indian Standard (Part III) was adopted by the Indian Standards Institution on 17 February 1981, after the draft finalized by the Reliability of Electronic and Electrical Components and Equipment Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 This guide is intended to make recommendations for the standardization of maintainability practices, and to stimulate ideas in the maintainability field. Organizations acquiring items will find the guide useful in assisting them in defining maintainability requirements and associated programmes. Item suppliers will benefit from use of the guide, gaining an understanding of the requirements for achieving and verifying maintainability objectives.

0.3 The present Guide is intended to be Part III of the Guide on Maintainability. Final publication of the complete series is expected to take some time but since each Part is able to make a contribution to the needs of other ISI Technical Committees it has been decided to circulate each Part as a separate document. The other Parts of this standard would be as follows:

Part I Introduction to maintainability

Part II Maintainability requirements in specifications and contracts

Part IV Test and diagnostic procedures

Part V Maintainability design studies

Part VI Maintainability verification

Part VII Collection, analysis and presentation of data related to maintainability.

0.4 In the preparation of this standard, assistance has been derived from the IEC Document 56 (Central Office) 70 Draft—'Guide on maintainability of equipment: Part 3 Maintainability Programme' issued by the International Electrotechnical Commission.

0.5 This standard is one of a series of Indian Standards on reliability of electronic and electrical components and equipment. A list of standards published so far in this series is given on page 16.

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1. SCOPE

1.1 This standard (Part III) covers the contents of a maintainability programme.

2. GENERAL ASPECTS OF A MAINTAINABILITY PROGRAMME

2.1 Introduction — This Guide is applicable where a contractual relationship exists between the contractor and the customer with a stated maintainability requirement. However, a maintainability programme may also be required in other cases when the same main principles will apply — for example where an item is produced for general sale, where the contractor and customer belong to the same organization or where the customer requires an evaluation of the achieved maintainability for some reason. The reader may have to consult other parts of the guide for further details.

2.2 Purpose — The cost of maintenance of an item will vary with its size and complexity as well as with its nature and the seriousness of the failures to which it is subject but may form a large proportion of the total cost of ownership. As it shall be an important target of a customer to minimize the total cost, whilst ensuring that all other requirements are met, it is essential that attention is paid to the maintainability of an item in the perspective of its whole life. It is also of great importance to achieve a high availability of the item. This can best be done by a formal maintainability programme, prepared at the definition phase, but flexible enough to be modified with experience of the project. The extent of the programme and hence its cost will vary with each and every project. However, the programme should be planned with due regard being paid to each of the steps described in **2** and **3**, setting a suitable level for each step.

NOTE — The definition phase of the system life cycle is devoted to translating system functional requirements generated during the conceptual phase into detailed system and system element requirements that will govern subsequent acquisitive efforts. During this phase, the reliability programme includes both assurance and achievement activities.

2.3 General Characteristics — The maintainability programme is governed by a detailed plan which includes procedures, tasks and responsibilities necessary to fulfil the maintainability requirements and to give a timely development of the maintenance support system. A formal programme is required for the following reasons:

a) To integrate the maintainability effort into the overall engineering effort,

b) To identify the various maintainability tasks and the responsibilities for carrying out these tasks,

c) To integrate the maintainability effort with that of sub-contractors and other outside organizations, and

d) To evaluate the cost of the programme itself for funding purposes.

The contractor is responsible for carrying out the maintainability programme, usually as a contractual responsibility. He will develop a maintainability programme plan, which will be the master management document for control, for the approval of the customer as early as possible in the acquisition programme.

A good maintainability programme can also lead to overall cost benefits to the contractor in terms of reduced costs of technical support, repair, replacement and warranties and in improved competitiveness and goodwill.

2.4 Integration of the Maintainability Programme with Other Activities — A maintainability programme cannot be carried out in isolation from other activities (particularly the reliability programme), and indeed it is an essential part of the whole engineering programme. It is necessary that reviews should be held to consider the status of the maintainability programme. Maintainability data should be gathered from all trials of the item [*see* IS:9692 (Part VII)] 'Guide on maintainability of equipment: Part VII Collection, analysis and presentation of data related to maintainability'. There may also be conflicting demnads on the design and these shall be resolved by appropriate compromises.

Note — Till such time the standard under preparation is published, the matter shall be as agreed to between the purchaser and the seller.

2.5 Qualitative and Quantitative Measurement of Maintainability — The aim of a maintainability programme is to ensure that the customer's requirements are met. These requirements will usually be stated in a formal specification and it is the responsibility of the contractor to interpret them into specific design features. Whether there are qualitative or quantitative requirements or both, a formal maintainability programme is the best way to secure customer satisfaction.

IS:9692 (Part II)-1980* of this guide discusses the various types of maintainability characteristics which may be established.

3. MAINTAINABILITY PROGRAMME

3.1 Nature of the Maintainability Programme — Throughout the life of an item, the maintainability programme brings together all the maintainability activities in an ordered and logical way and assures full documentation and integration with other engineering activities.

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*Guide on maintainability of equipment: Part II Maintainability requirements in specifications and contracts.

3.2 Summary of the Programme — The essential elements of the maintainability programme are listed below and then expanded in subsequent paragraphs.

Each element should be carefully considered in the formulation of the final programme.

a) Preparation of a maintainability programme plan (*see* **3.3**)

b) Establishment of a system for programme reviews (including the cost aspect) (*see* **3.4**)

c) Determination of design criteria and allocation of requirements to sub-divisions of the item (*see* **3.5**)

d) Maintainability evaluation and prediction (*see* **3.6**)

e) Inclusion of maintainability requirements in subcontractor and vendor specifications (*see* **3.7**)

f) Establishment of a data collection, analysis and corrective action system (*see* **3.8**)

g) Participation in design reviews (*see* **3.9**)

h) Ease of maintenance studies (*see* **3.10**)

j) Preparation of data for maintenance planning (*see* **3.11**)

k) Establishment of a control system for design or process changes (*see* **3.12**)

m) Maintainability verification (*see* **3.13**)

NOTE — This list is not necessarily complete and some elements may be sub-divided.

3.3 Maintainability Programme Plan — The plan is a document describing in some detail how the contractor intends to manage his maintainability effort and to supervise that of his sub-contractors.

3.3.1 *Scope of the Programme Plan* — The programme plan shall interpret the specified requirements in terms of tasks and responsibilities and will enable the programme to be integrated into the whole effort. It shall also describe the procedures to be followed to enable to contractor to establish control of the programme.

3.3.2 *Organization* — The plan shall contain details of the overall organization responsible for the maintainability effort. In particular it shall:

a) identify the elements of the organization and the key personnel responsible for managing the maintainability programme;

b) define their responsibilities and functions and their interrelationships; and

c) stipulate their authority.

3.3.3 *Tasks and Responsibilities* — The plan shall detail tasks which have to be carried out. For each of these tasks, the plan should include the following information:

a) A detailed description of the task including the specific objectives which shall be met at various stages of the programme;

b) The stages of the task related to the total plan. The number of stages shall be sufficient to ensure satisfactory control of the task. Each stage should be described in terms of the information to be made available for review purposes;

c) The procedures to be used to evaluate the stages of the task and to establish control. It shall include details of the organizational elements responsible for executing the task and their authority; and

d) Identification of problems which are expected from prior knowledge of the task and the proposed actions to be taken for their solutions.

3.3.4 *Maintainability Status Reporting* — At intervals determined or approved by the customer, the contractor shall prepare maintainability status reports which provide a current accounting of required, allocated, predicted and observed values for the item and the sub-divisions into which it has been broken down for maintainability analysis. The reports shall include a narative and graphical treatment of trends, problems encountered or anticipated, and action taken or proposed. These reports may be combined with other programme documentation but maintainability information should be summarized in a separate section.

3.3.5 *Associated Activities* — The maintainability programme shall be co-ordinated with other activities, and the programme plan shall detail the procedures necessary to assure that this is done. The following is a list of the common activities concerned but in some cases some of them may combined:

a) Design engineering;

b) Reliability engineering;

c) Maintenance planning;

d) Human engineering, human factors and training;

e) Safety engineering;

f) Quality assurance;

g) Production engineering;
h) Standardization;
j) Configuration management;
k) Value engineering; and
m) Integrated logistic support.

3.4 Programme Reviews — An estimate of the costs of the maintainability programme should be made at the contract stage and constantly be updated. They shall include the costs of any extra effort required in design and production in support of the programme. These estimates which should be the basis for the funding of the programme shall be used by the customer to decide whether the programme is cost effective, that is, whether the extra expenditure shall bring benefits in the form of reduced maintenance costs and higher availability and in other forms of intangible benefits to the customer. Programme reviews should be held at regular intervals to consider the achievements of the programme and to approve any changes.

3.5 Determination of Design Criteria and Allocation of Requirements to Sub-Divisions of the Item — In the first phase of design, an analysis of the qualitative and quantitative maintainability requirements should be carried out. The analysis will translate these inputs into qualitative design criteria and into detailed quantitative maintainability requirements for the sub-divisions of the item through an allocation process. The outputs of this analysis shall be used during design, development and test to assess the degree of achievement of the maintainability design requirements. This analysis shall take into account:

a) The overall maintainability requirements;
b) The environmental conditions of use including the operating and maintenance support conditions;
c) The facilities available for maintenance, training programme, the personnel skills, the maintenance equipment and tools at each level of support;
d) Any cost or other restraints; and
e) Design studies already carried out.

3.5.1 The maintainability design guidelines are given in Appendix A.

3.6 Maintainability Evaluation and Prediction — This activity is directly related to the one described in **3.5** but it is carried out in greater depth and at a later point in the design phase.

Study efforts during this phase are directed towards assuring a design satisfying the allocated design requirements and the design criteria for maintainability. This is done through a continuous participation, by the maintainability engineer, in the design process performing analysis, seeking opportunities for improvement.

Another effort during this phase is a periodic prediction of maintainability characteristics thus assessing fulfilment of overall item maintainability requirements. The prediction technique used shall be specified or approved by the procuring organization. Deviations shall be transferred into new allocated requirements and trade-offs. The latter effort shall also give a basis for status reporting (*see* **3.3.4**) and submittal of maintenance planning data (*see* **3.10**).

3.7 Maintainability Requirements in Sub-Contractor and Vendor Specifications — The main contractor is responsible for maintainability of the entire item, thus he shall ensure that maintainability programmes as appropriates are carried out by his sub-contractors and vendors.

Based on the results of maintainability analysis (*see* **3.5**), he shall include appropriate quantitative maintainability requirements in specifications for designated sub-contractor and vendor supplied sub-items procured for the item. These requirements shall be stipulated in terms suitable for demonstration. Specifications for sub-contractor and vendor sub-items shall include, where applicable, such information as:

a) Item constraints and requirements;

b) Maintenance concepts and support requirements;

c) Standardization and interchangeability requirements; and

d) Maintainability demonstration requirements and procedures.

The main contractor shall stipulate the procedures for assuring that the sub-contractor's and vendor's maintainability procedures are consistent with overall item requirements and that adequate surveillance of the sub-contractor's and vendor's will be maintained to enforce compliance with all maintainability requirements specified.

3.8 Data Collection, Analysis and Corrective Action System — The contractor shall establish a maintainability data collection system for prediction during design and for evaluation of demonstration results. Data should be collected from all tests and trials, whether design, development or customer trials to assist in verifying that the maintainability requirements are being met and to reduce the need for special maintainability trials which may be expensive. Care shall be taken when using such data to ensure that the conditions of the trial are related to the conditions of use and the maintenance organization of the customer.

The contractor shall analyse the data against maintainability, quantitative and qualitative requirements, identify problems, recommend solutions, record corrective actions, and include data collected which confirm the effectiveness of the corrective action.

Consideration should be given to the use of the same data collection system during the early use period.

3.9 Design Reviews — The appropriate elements of the maintainability programme should be considered at each design review. Additional review points may be required for the maintainability programme and this should be stated in the programme plan.

All design changes shall be reviewed and their effects on the achievement of maintainability requirements evaluated. A final review shall be made prior to release of drawings and specifications for production. Formal review procedures shall be established and scheduled in the maintainability programme plan.

3.10 Ease of Maintenance Studies — At appropriate times when items are available, the contractor should carry out experimental studies on the maintenance tasks which he has defined as necessary. Priority shall be given to those tasks which are expected to be more frequent, that is, areas of low reliability, areas where wear-out is expected and routine preventive maintenance tasks. These studies may lead to design changes for improvement of maintainability and may also identify any requirements for special facilities, maintenance equipment and tools to reduce the maintenance downtime. The studies may also result in recommendations on the skills required for maintenance personnel and hence their training.

3.11 Data for Maintenance Planning — The contractor shall prepare inputs for establishing a maintenance concept and for establishing an item maintenance plan. The initial step in the development of inputs to the plan shall be the preparation of inputs to a detailed maintenance concept, which shall evolve through repetitive maintainability analysis (*see* **3.6**) into a maintenance plan for supporting the operation of the item in the planned operational environment. Typical outputs of the analysis which are included in the maintenance plan are:

a) Depth and frequency of maintenance at various levels of support;

b) Requirements for special facilities;

c) Requirements for special maintenance equipment and tools;

d) Requirements for spares;

e) Skill levels and numbers of maintenance personnel required; and

f) Predicted costs of maintenance.

3.12 Control System for Design or Process Changes — Through the maintainability programme it should be ensured that the design features which affect maintainability are faithfully reproduced in production and quality assurance documents. Any changes to these documents which are proposed during the manufacturing phase should be examined for their effect on maintainability.

Any change should be notified to the engineer responsible for maintainability in design, who should examine the implication of the change on the maintainability of the item. Similarly any change he proposes to improve maintainability should be examined for its effect on performance, reliability and costs. An integrated procedure to process such changes shall be included in the programme plan.

3.13 Maintainability Verification — The achievement of maintainability requirements shall be verified as specified in the contract. The verification shall normally be accomplished in accordance with IS : 9692 (Part VI) 'Guide on maintainability of equipment: Part VI Maintainability verification' which includes contractor preparation and submission of a demonstration plan and report to the customer. The demonstration plan shall be responsive to the maintainability programme plan established by this Guide. Maintainability demonstration efforts shall be integrated with other system testing requirements such as proof of design, bread board, prototype, environmental, production and acceptance. Maintainability demonstration data shall be used to verify the achievement of maintainability design requirements and to update the maintainability parameter values from the maintainability analysis and prediction. The formal maintainability demonstration performed to determine contract compliance shall be conducted in an operational or simulated operational environment as specified in the contract. Maintainability verification data shall be used to verify by successive approaches the achievement of maintainability design requirements and to update the assessed maintainability characteristics.

Note — Till such time the standard under preparation is published, the matter shall be as agreed to between the purchaser and the seller.

4. CONTRACTOR'S RESPONSIBILITIES

4.1 The contractor is responsible for producing the maintainability programme plan and executing the programme. He shall constantly review it as development proceeds; in particular at each review point he shall report on the status of the programme.

4.2 The contractor shall report at once to the customer when he believes that the maintainability requirements may not be met or where there is a conflict with another requirement such as operational performance, reliability and costs. Where possible he should propose other solutions.

5. CUSTOMER'S RESPONSIBILITY

5.1 The customer's responsibility begins with his preparation of a maintainability specification that clearly details the maintainability characteristics (requirements) to be met by the item to be acquired. Further, the scope of the maintainability programme required to be performed by the contractor should be identified. Constraints that customer's intended use environment will place on the item's maintainability design and maintenance support planning shall be communicated to the potential contractor(s) (*see* Appendix B).

5.2 During negotiation for the item's acquisition, the customer shall receive the potential contractor's proposed maintainability programme to assure that his requirements have been properly understood. Clarifications should be requested from the contractor(s) for any points of concern.

5.3 After initiation of the item's acquisition the customer shall receive and approve the contractor's detailed maintainability programme plan. Participation by the customer may be required in the periodic maintainability design reviews along with his observance of verification (acceptance) tests. The customer may also be required to review contractor's prediction and other maintainability analysis reports.

6. DIALOGUE BETWEEN CUSTOMER AND CONTRACTOR

6.1 In formulating a maintainability programme and executing, it is essential that there should be continuous liaison between the maintenance support planning staff of the customer and the maintainability engineering staff of the contractor. The customer's staff shall be aware of and have experience in the problems of design for maintainability and its interface with that of other requirements. The contractor's staff shall be aware of the problems of maintenance support, particularly of the skill levels of maintenance personnel, facilities, equipments and tools already available and the environment in which maintenance work is to be carried out.

As far as possible, data should be passed between them in a way in which it may readily be used without requiring interpretation or reprocessing. These communication procedures shall be defined in the programme plan, particularly in respect of specific data items, the timing and the channels of communication.

7. FURTHER DETAILS RELATED TO THIS PART OF THE GUIDE

7.1 This part has necessarily been kept concise. The activities are described in more detail in later parts of this standard (*see* **0.3**).

APPENDIX A

(*Clause* 3.5.1)

MAINTAINABILITY DESIGN GUIDELINES

A-1. The following are some of the maintainability design guidelines which should be considered for incorporation into the design:

a) Reduce the complexity of maintenance by:

   i) Providing adequate accessibility, work space, and work clearance.

   ii) Providing for interchangeability of like components, materials and parts within the system/equipment.

   iii) Utilizing standard parts and items.

   iv) Limiting the number and variety of tools, accessories and support equipment.

   v) Insuring compatibility among system equipment and facilities.

b) Reduce the need for and frequency of design-dictated maintenance activities by using:

   i) Fail-safe features.

   ii) Components which require little or no preventive maintenance.

   iii) Tolerances which allow for use and wear throughout life.

   iv) Adequate corrosion prevention/control features.

c) Reduce maintenance downtime by designing for:

   i) Rapid and positive detection of malfunction or degradation.

   ii) Rapid and complete preparation to begin maintenance.

   iii) Rapid and positive localization of malfunctions to the repair level for which skills, spares and test equipment are planned.

   iv) Ease of fault correction.

   v) Rapid and positive adjustment and calibration.

   vi) Rapid and positive verification of correction.

d) Reduce design-dictated maintenance support costs by limiting:

   i) The need for specialized maintenance tools, support equipment and facilities.

  - ii) The requirements for depot or factory maintenance, consistent with system/cost effectiveness.
  - iii) The need for extensive maintenance technical data.

- e) Limit maintenance personnel requirements by applying human engineering principles such as:
  - i) Identification and accessibility of parts, test points, adjustments and connections.
  - ii) Easy handling, mobility, transportability and storability.
  - iii) Logically sequenced maintenance tasks.
  - iv) A feasible range of relevant personnel physiological parameters.

- f) Reduce the potential for maintenance error by designing to eliminate:
  - i) The possibility of incorrect connection/assembly/installation.
  - ii) Dirty, awkward, and tedious job elements.
  - iii) Ambiguity in maintenance labelling, coding and technical data.

APPENDIX B

(*Clause* 5.1)

EXAMPLES OF THE INFORMATION THE CUSTOMER SHOULD GIVE TO THE CONTRACTOR

B-1. REFERENCES TO APPROPRIATE SPECIFICATION OR DOCUMENTS

B-2. GENERAL INFORMATION

B-2.1 Definition or Description of the Item

B-2.1.1 *Mission Profile*

- a) Functions of the differents sub-items and their relative importance.
- b) Phases to be considered, if any.
- c) Duration of each phase.
- d) Different modes of operation.
- e) All other constraint.

B-2.1.2 *Characteristics of the Item*

a) Operational characteristics.
b) Periods of usages (duration, constraints).
c) Reliability characteristics.
d) Duration of service.

B-3. INFORMATION ON THE PRODUCTION

a) Number to be deployed.
b) Delivery plan.

B-4. MAINTENANCE POLICY

a) Level of use.
b) Maintenance organization.
c) Maintenance levels.
d) Number of storage points.
e) Procurement lead times.
f) Technical assistance requested.

B-5. DESIGN REQUIREMENTS AND CONSTRAINTS

B-6. MAINTAINABILITY REQUIREMENTS

B-7. MAINTAINABILITY REPORTS REQUIRED

B-8. MAINTENANCE DOCUMENTATION

B-9. MAINTAINABILITY VERIFICATION

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IS:

1885 (Part XXXIX)-1979 Electrotechnical vocabulary: Part XXXIX Reliability of electronic and electrical items (*first revision*)

2612-1965 Recommendation for type approval and sampling procedures for electronic components

7354 Guide on reliability of electronic and electrical items:

- (Part I)-1975 Preliminary reliability considerations
- (Part II)-1975 Managerial aspects of reliability
- (Part III)-1975 Presentation of reliability data on electronic and electrical components (or parts)
- (Part IV)-1974 Collection of reliability, availability and maintainability data from field performance
- (Part V)-1975 Inclusion of lot-by-lot and periodic inspection procedures in specifications for electronic and electrical components (or parts)
- (Part VI)-1975 Inclusion of reliability clauses into the specifications for components (or parts)

7690-1975 Mathematical guide to the terms and definitions for reliability of electronic equipment and components (or parts) used therein

8161 Guide for equipment reliability testing:

- (Part I)-1976 Principles and procedures
- (Part VII)-1977 Compliance test plans for failure rate and mean time between failures assuming constant failure rate

9185 Endurance (life) test for electronic and electrical components:

- (Part I)-1979 Thermal endurance
- (Part II)-1979 Mechanical endurance

9186-1979 Guide for screening of electronic and electrical items

9692 Guide on maintainability of equipment:

- (Part I)-1980 Introduction to maintainability
- (Part II)-1980 Maintainability requirements in specifications and contracts